4.2 WATER AND SEDIMENT QUALITY

This section assesses potential impacts to water and sediment quality compared to current conditions within Santa Monica Bay and the Southern California Bight (SCB) from the Chevron El Segundo Marine Terminal Lease Renewal Project (Project). The proposed Project would involve the continuation of existing operations at the Chevron El Segundo Marine Terminal for an additional 30 years. Future maintenance activities, incremental increases in throughput, and an expected increase in vessel calls could impact water and sediment quality. Although routine Marine Terminal maintenance activities will likely have only temporary and localized effects on the water column and marine sediments, propeller wash from the tanker vessels visiting the terminal erodes sediments beneath the berths, and an increased number of vessel calls could marginally expand this erosion footprint. Additionally, increases in vessel calls would increase the potential for accidental oil spills, which would have potentially significant impacts to water and sediment quality.

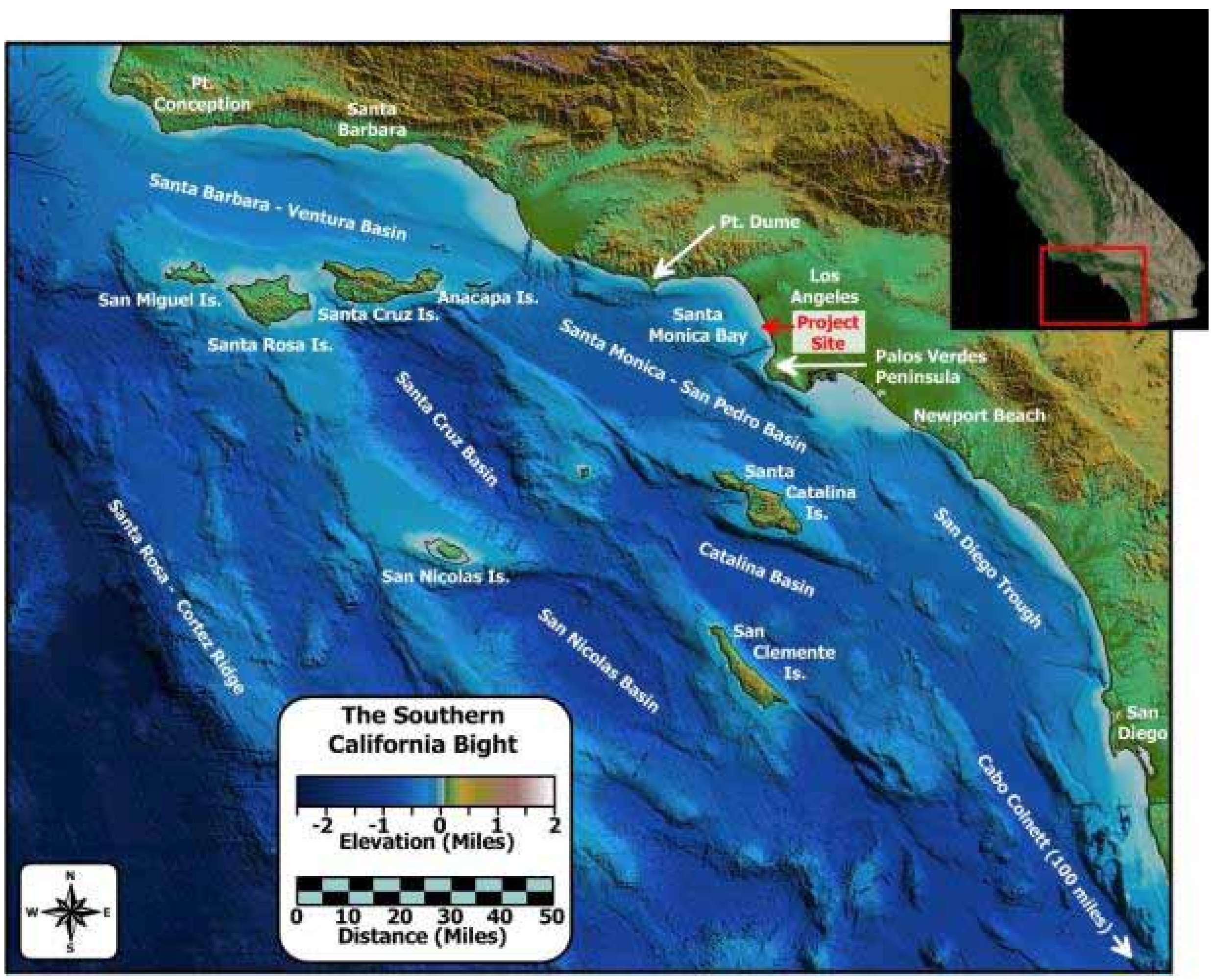
As defined in Section 13050 of the California Water Code, water-quality inputs of concern include discharges that create pollution, contamination, or nuisance or that release toxic substances deleterious to humans, fish, bird, or plant life. In that regard, an accurate assessment of potential marine oil-spill impacts is central to the impact evaluation. Consequently, this assessment of potential water-quality impacts relies heavily on spill-modeling results described in Section 4.1, System Safety and Reliability, which are further detailed in Appendix C, Oil Spill Modeling. Appropriate mitigation measures are provided for those sediment and water-quality impacts determined to be potentially significant. Moreover, the significance of many water-quality impacts are inextricably linked to adverse effects on marine and estuarine species that could result from a potential spill; Section 4.3, Biological Resources, details these biological impacts.

4.2.1 Environmental Setting

This subsection characterizes the baseline physical and chemical environment surrounding the Project site as it pertains to the existing quality of sediments and surface, ground, and ocean waters. The proposed Project and its alternatives could potentially impact the quality of waters and sediments, and the severity of those impacts are a function of the Project's location within the physiographic environment, the physicochemical properties of receiving waters and sediments, the circulatory and dispersive capacity of the regional oceanographic regime, and the present levels of contamination. This subsection discusses each of these four aspects of the environment in detail.

The coastline along much of the SCB is heavily urbanized, with more than 12 million people living along the coastal corridor between Point Dume at the northern end of Santa Monica Bay and Newport Beach (see Figure 4.2-1). Pulses of stormwater runoff carry concentrated contaminants, which have accumulated onshore during long dry spells, into the Bay over the relatively short storm duration. Additionally, ocean outfalls currently discharge treated effluent and other materials into the middle of Santa Monica Bay and the southern end of the Palos Verdes shelf. Historically, effluent with relatively high levels of chemical contaminants was also discharged near both of these locations.

Figure 4.2-1
Project Location within the Southern California Bight



Together, these discharges have been a historical source of chemical and biological contaminants found within the Bay and the surrounding bight. Although some synthetic organic contaminants sorb onto fine sediment particles and are initially deposited near the discharge location, they can be repeatedly resuspended by surface gravity waves, internal waves, or coastal currents, and transported far from the source (Noble and Xu 2003). More than 90 percent of surficial sediment within the Bay is contaminated, often at levels of potential biological concern (Schiff 2000). Other contaminants, such as bacterial and viral pathogens, can remain suspended in the water column where they are transported over great distances by coastal currents.

Physiography

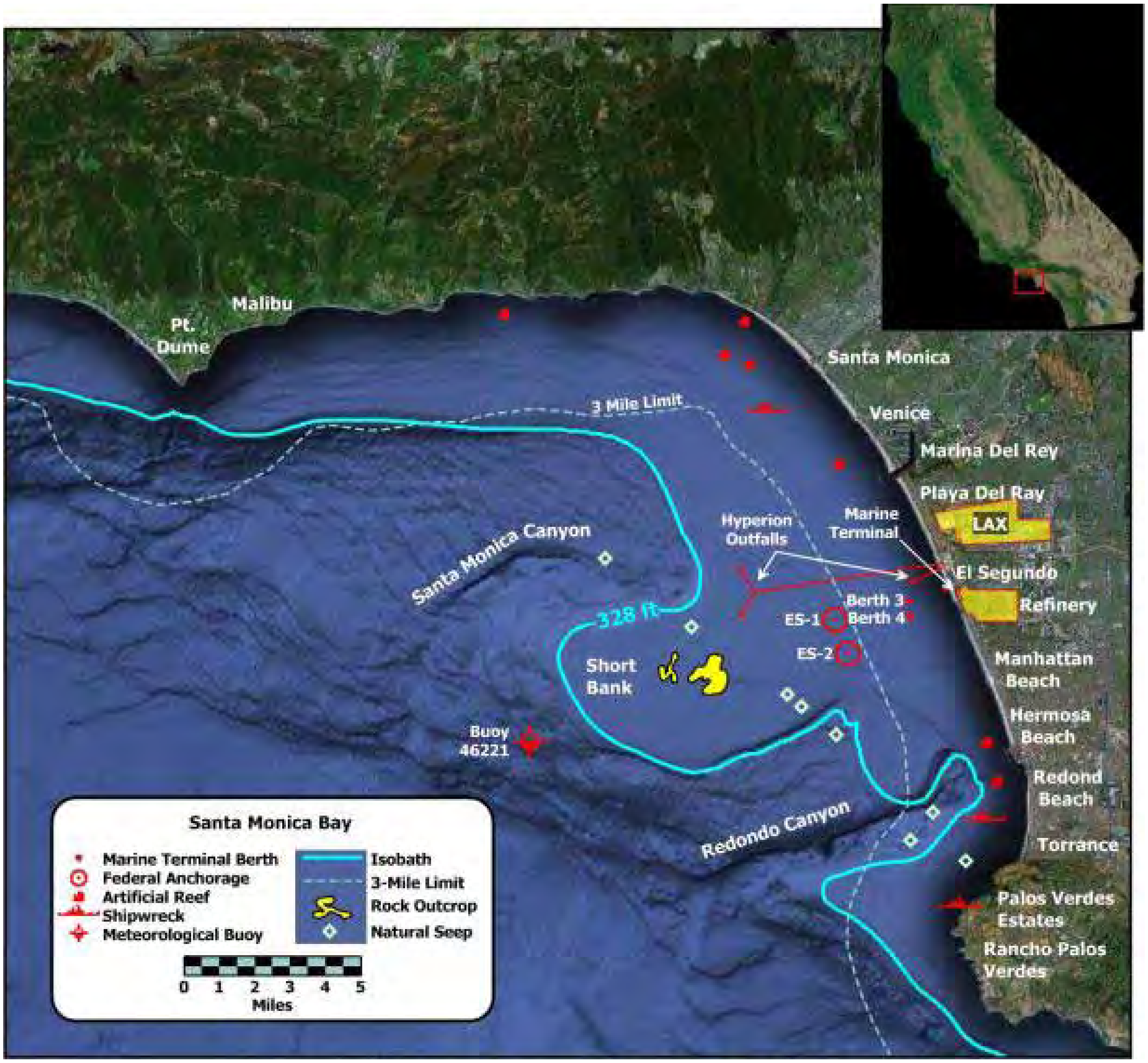
The SCB encompasses an area between Point Conception to the north and Cabo Colnett in Baja California, Mexico, to the south, extending offshore westward to the Santa Rosa-Cortez ridge (see Figure 4.2-1). The proposed Project lies within Santa Monica Bay, which is a comparatively shallow subarea of the SCB. The Bay stretches from Point Dume in the north to the northern tip of the Palos Verdes Peninsula in the south. Santa Monica Bay extends seaward approximately 11 miles (17.7 kilometers [km]) to a break in the coastal shelf at a depth of approximately 328 feet (100 meters [m]) (see Figure 4.2-2).

The onshore portion of the coast bordering Santa Monica Bay varies significantly in its topography, with a mountainous northern area, a central region dominated by flat, sandy beaches, and the rocky cliffs of the Palos Verdes Peninsula to the south. Santa Monica Bay is bordered by the cities of Malibu, Santa Monica, Venice, Marina del Ray, Playa del Ray, El Segundo, Manhattan Beach, Hermosa Beach, Redondo Beach, Torrance, Palos Verdes Estates, and Rancho Palos Verdes (from north to south, see Figure 4.2-2).

Freshwater Inflow

Freshwater inflow to the Santa Monica Bay comes from municipal and industrial wastewater discharges, surface runoff, creeks, and rivers, as well as dry streambeds that terminate in the Bay. Major freshwater sources include Malibu Creek, Topanga Creek, and Ballona Creek. The two largest drainage areas are the Malibu Watershed, northwest of the Project site, and the Ballona Watershed, immediately north of the Project site. Overall, an area of approximately 414 square miles (1,072 square kilometers [km^2]) drains into the Bay (see Figure 4.2-3).

Figure 4.2-2
Project Location within Santa Monica Bay

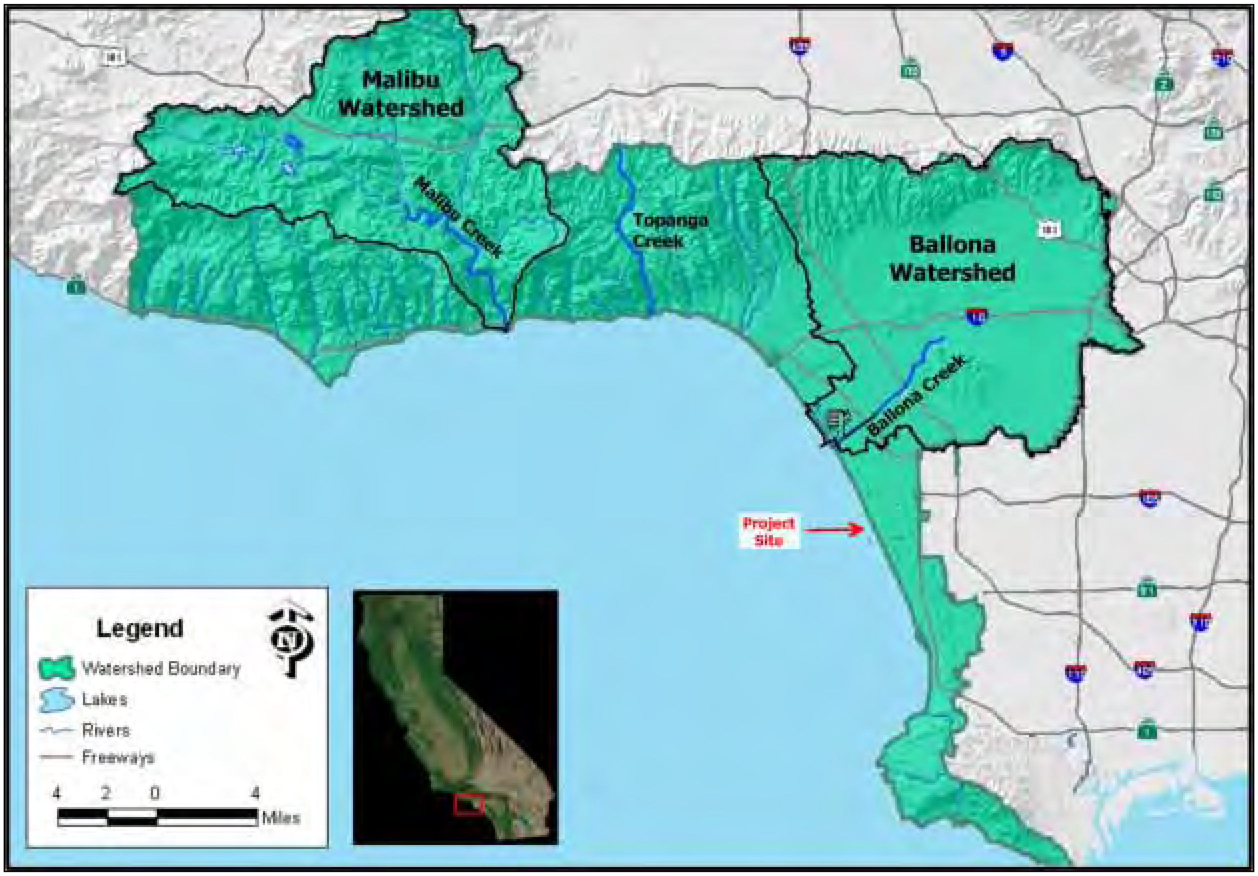


Source: Google Earth 2009, Wilkinson 1971

The Malibu Creek watershed encompasses undeveloped mountain areas, large-acreage residential properties, and many natural stream reaches, while Ballona Creek is predominantly channelized and highly developed with both residential and commercial properties. A majority of the 193 National Pollutant Discharge Elimination System (NPDES) permitted facilities in the watershed discharge to Ballona Creek (LARWQCB 2007a). Significant sediment and water-quality issues related to Ballona Creek include trash loading, wetlands restoration, trace-organic and heavy metal contamination of creek-mouth sediments, toxicity of both dry-weather and stormwater runoff, and high bacterial indicators at the creek mouth.

Figure 4.2-3

Map of the Santa Monica Bay Watershed Management Area



Source: LARWQCB 2007b

Rainfall and the associated freshwater inflow to the SCB are episodic within any given year, and also vary substantially among years (Jenkins and Wasyl 2005). California's coastal climate varies in cycles that last 20 to 30 years. For example, the dry period extending from 1945 to 1977 was followed by an episodically wet period from 1978 to 1998 that included six strong El Niño events (Goddard and Graham 1997). El Niño events are intense, abrupt global modifications of the typical seasonal weather cycle. These events bring unusually heavy rainfall to the SCB and markedly increase the northward transport of warm subtropical water into the region.

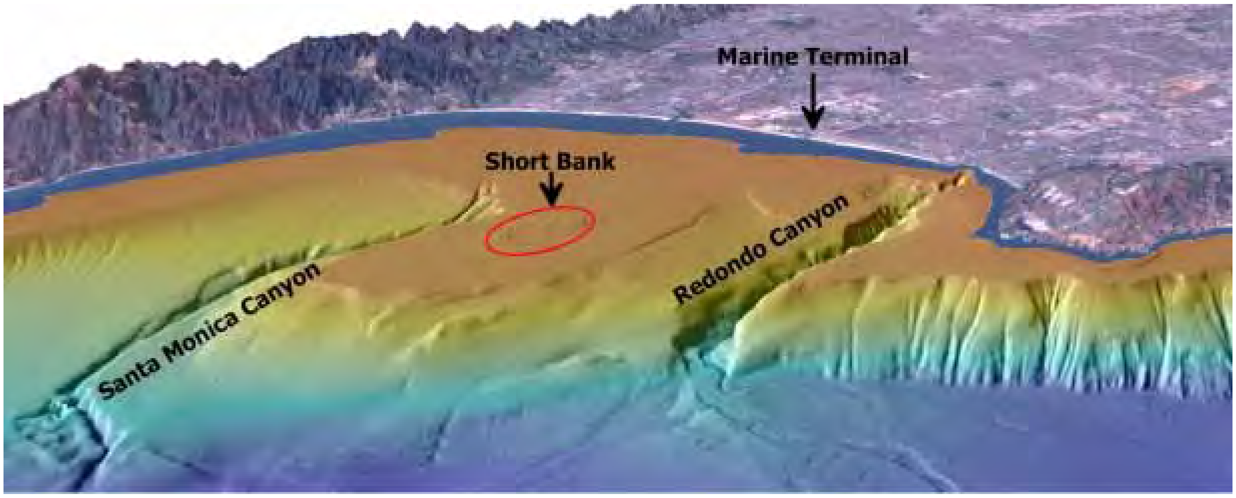
The intense storms associated with strong El Niño events generate large waves that impinge on the SCB shoreline and cause significant shoreline erosion. During the particularly severe El Niño event that started in 1982, severe beach erosion in front of the Marine Terminal led to the construction of the El Segundo rock groin to protect the Terminal and its cross-shore pipelines. Based on the historic record of multi-decade climate cycles, 1998 was the end of a wet period in California, followed by a return to a dry climate regime (White and Cayan 1998). As a result, stormwater flow into the SCB will likely decline and severe erosion of the beach in front of the Marine Terminal from severe El Niño storms will be less likely during most of the proposed Project's upcoming lease term.

Seafloor Substrates

Intertidal zones within the Bay consist predominately of sand beaches, although rocky shores, tidal flats, coastal marshes, and man-made structures occur along localized sections of the shoreline. Sandy and soft-bottom habitats dominate subtidal substrates within the Bay in all depth zones, with the occurrence of hard-substrate seafloor features relatively uncommon. Near the Project site, hard-substrate seafloor features are generally localized and of man-made origin, consisting of jetties, seafloor debris, and artificial reefs. Rock outcrops, with their higher relief and structural complexity, are primarily located along the northern and southern portions of the Bay.

Short Bank is the only naturally occurring deep rocky area in the Bay, although the walls of the two adjacent submarine canyons also support consolidated sediment surfaces (see Figure 4.2-4). Santa Monica Canyon lies in deep water near the center of the Bay, while the deeply incised Redondo Canyon extends to the shoreline approximately five miles (8.0 km) south of the Marine Terminal.

Figure 4.2-4
Perspective View of Santa Monica and Redondo Canyons



Source: Gardner et al. 1999

Coastal Features

Artificial reefs and shipwrecks, although anthropogenic in origin, provide limited but valuable hard-substrate habitat within the Bay. However, few of these seafloor features are located in the immediate vicinity of the Marine Terminal (see Figure 4.2-2). In 2008, a nearshore artificial reef known as Chevron Reef or Pratte's Reef was removed from a location immediately north of the Marine Terminal (Figure 4.2-5). The reef was installed in 2000 to enhance recreational surfing and mitigate the potential loss of surfing areas due to construction of the El Segundo Groin and associated backfilling on Dockweiler Beach. Since the removal of the reef, the El Segundo Groin remains the only notable coastal feature immediately adjacent to the Marine Terminal. The Grant Street Groin, which extends offshore of the Scattergood Power Plant to the north, is much shorter. The Hyperion Wastewater Treatment Plant's outfall, which is exposed subtidally, lies farther north.

Figure 4.2-5

Aerial Photograph of Coastal Structures near the Marine Terminal along the Southern Portion of Dockweiler Beach

Source: Perry 2006

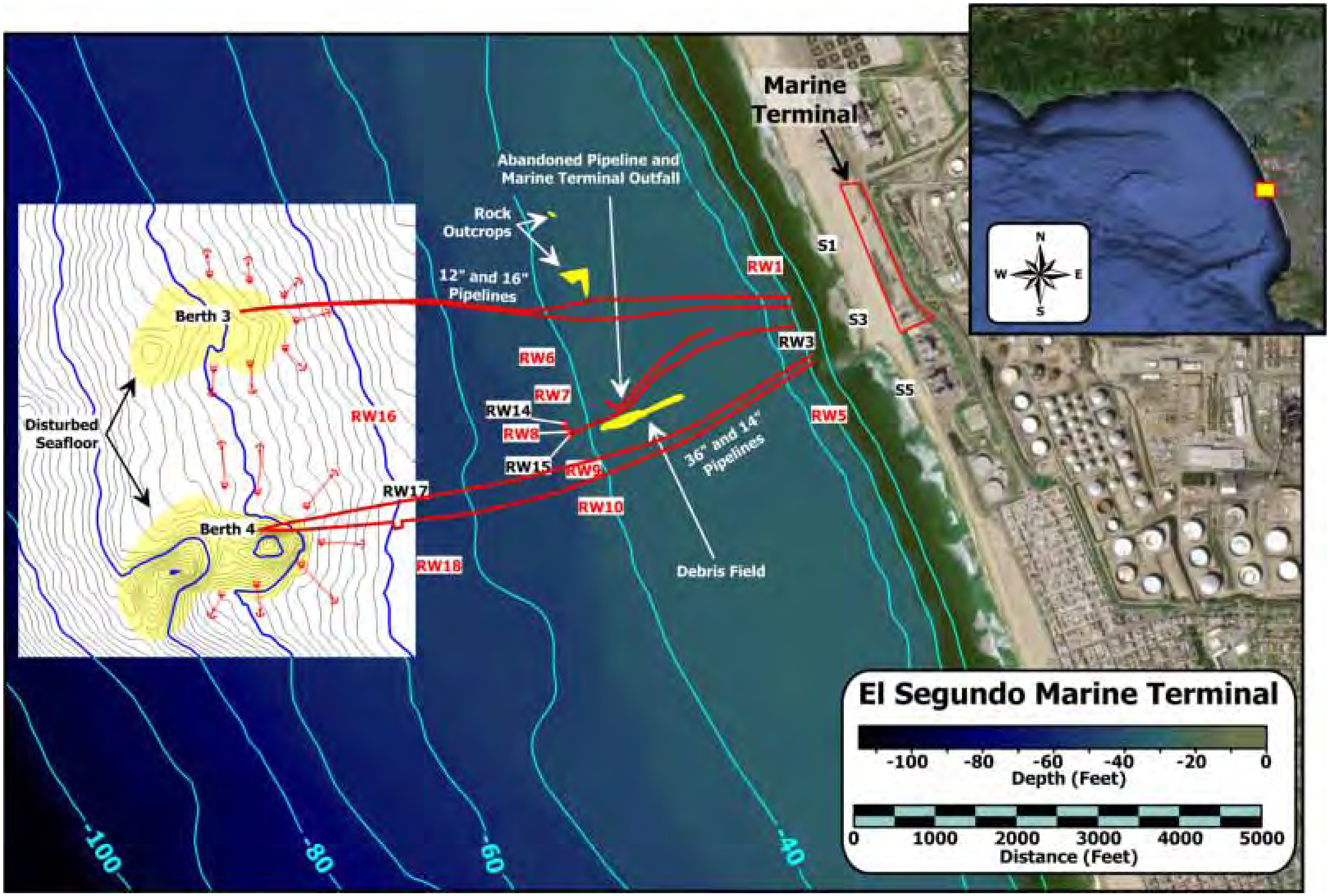
Subtidal seafloor features immediately offshore of the Marine Terminal are primarily related to the operations of Chevron's El Segundo Refinery (Refinery) and the Terminal (see Figure 4.2-6). These features were identified in high-resolution bathymetric surveys conducted near Berths 3 and 4 (Fugro 2004, 2007). Two localized areas of hard substrate, located along the 40-foot isobath north of Berth 3's pipeline systems, were identified as rock outcrops, presumably of natural origin. In contrast, a man-made debris field was identified near the Refinery's wastewater outfall, between the pipeline systems for Berths 3 and 4. The debris field may be associated with an abandoned pipeline, or with the presently active Refinery outfall adjacent to the abandoned pipeline. Relief heights within the field are less than three feet (0.9 m) above the seafloor.

The active Refinery outfall extends 0.7 miles (1.1 km) offshore and terminates at a diffuser structure at a depth of 42 feet (12.8 m). Thirteen water-quality monitoring stations, distributed around the discharge point, are sampled quarterly (LARWQCB 2006). Their locations are designated with an "RW" prefix in Figure 4.2-6. Three surfzone stations, designated with an "SZ" prefix, are monitored monthly. Annual monitoring of benthic infauna and chemistry is conducted at a nine-station subset of receiving-water stations, shown in red. Station RW16 is proximal to both tanker-mooring berths. Monitoring at that station provides site-specific baseline sediment and water-quality information for the berth areas that is discussed in subsequent subsections.

Seafloor depressions are apparent beneath and west of both Marine Terminal berths (shown by yellow shading in Figure 4.2-6). The two especially deep bathymetric irregularities near Berth 4 have been ascribed to scour from vessel propeller wash (Fugro 2007). However, given that the dimensions, spatial orientation, and shape of the broader seafloor depressions are consistent with a large tanker-vessel moored within the berth, it is plausible that scour from propeller wash during mooring and unmooring operations is responsible for the observed seafloor alternations beneath and west of each berth. Large tanker vessels, nearly 1,000 feet (305 m) long, extend offshore from the mooring pattern and encompass the area of observed seafloor disturbance, which extends toward the west of the anchor patterns shown in Figure 4.2-6.

1 **Figure 4.2-6**

2 **NPDES Monitoring Stations, Seafloor Bathymetry, and Berth Configurations**



3 Source: Fugro West, Inc. 2004, 2007

Spatial analysis of the high-resolution bathymetric data was conducted as part of this environmental review (Table 4.2-1). It quantified the planar surficial area of the mooring-related seafloor modifications and the volume of material removed below grade at the time of the bathymetric survey. As described in subsequent sections, these bathymetric modifications are used to project potential impacts from a possible increase in vessel calls and to compare alternatives, such as relocation of the mooring berths farther offshore in deeper water depths.

Table 4.2-1
Dimensions of Disturbed Seafloor beneath the Mooring Berths

Dimension	Berth 3	Berth 4	Total
Planar Area in Acres (hectares)	40 (16.4)	62 (25.0)	102 (41.4)
Volume in Cubic Yards (cubic meters)	71,400 (54,600)	439,300 (335,900)	510,700 (390,500)

Note: One acre = 4,840 square yards; one hectare = 10,000 square meters

Based on the bathymetric analysis, present operations at the Marine Terminal have impacted 102 acres (41.3 hectares) of seafloor. Larger vessels call on Berth 4, and consequently, the scour area beneath Berth 4 is 53 percent larger than beneath Berth 3. Differences in vessel draft are even more apparent from the markedly deeper maximum scour depth beneath Berth 4, where excavation depths reach 14 feet (4.3 m) below grade, compared to two feet (0.6 m) beneath Berth 3. As a result, the estimated volume of sediments removed by propeller wash at Berth 4 is six times greater than at Berth 3.

Oceanography and Meteorology

A wide variety of oceanographic and meteorological processes affects the fate and effects of contaminants introduced into the SCB. As described in Section 4.1, System Safety and Reliability, and Appendix C, Oil Spill Modeling, winds and surface currents dictate the transport of oil accidentally spilled into the marine environment. This includes spills that could occur in conjunction with vessel transport to the Marine Terminal and during cargo transfer at the Marine Terminal, including leaks from seafloor pipelines. Even the physical fate of subsurface releases is largely dictated by surface winds and currents because petroleum hydrocarbons quickly ascend to the sea surface, where spill-related water-quality impacts tend to be localized.

Conversely, potential sediment and water-quality impacts from propeller-wash scour, mooring and pipeline maintenance activities, and marine construction activities associated with mooring relocation under two of the Project alternatives tend to have a greater subsurface effect. Consequently, subsurface currents tend to play a greater role in the physical fate of contaminants released during those activities. Near the Marine Terminal, turbulence generated by shoaling surface gravity waves, internal bores, and tides plays a role in dispersing and transporting contaminants suspended within the water column.

Wind and Rain

Winds within Santa Monica Bay are usually light and exhibit a diurnal variation throughout most of the year (Morris 2006). From evening until early morning, winds are often directed offshore, and they reverse direction to blow onshore after late morning. The heating and cooling of the land situated next to cool coastal waters establishes cross-shore atmospheric pressure gradients that drive these diurnal land-sea breezes. Afternoon land-sea breezes frequently range from 10 to 15 miles per hour (mph) (16.1 to 24.1 kilometers per hour [km/h]). During the evening, when the relatively warm and dry onshore air mass moves over cooler coastal waters, the layer of air in direct contact with the water surface is both cooled and moistened. The resulting marine layer often brings overcast conditions to coastal areas of Santa Monica Bay. During the day, stronger insolation tends to erode the marine layer in conjunction with wind-induced vertically mixing of the lower atmosphere.

While severe wind events are uncommon within the Bay, strong offshore Santa Ana winds can occasionally reach hurricane strength below passes and canyons surrounding the Bay. In addition, passing winter storms can bring southeast winds to gale force. However, for the most part, damaging winds tend to be rare or highly localized.

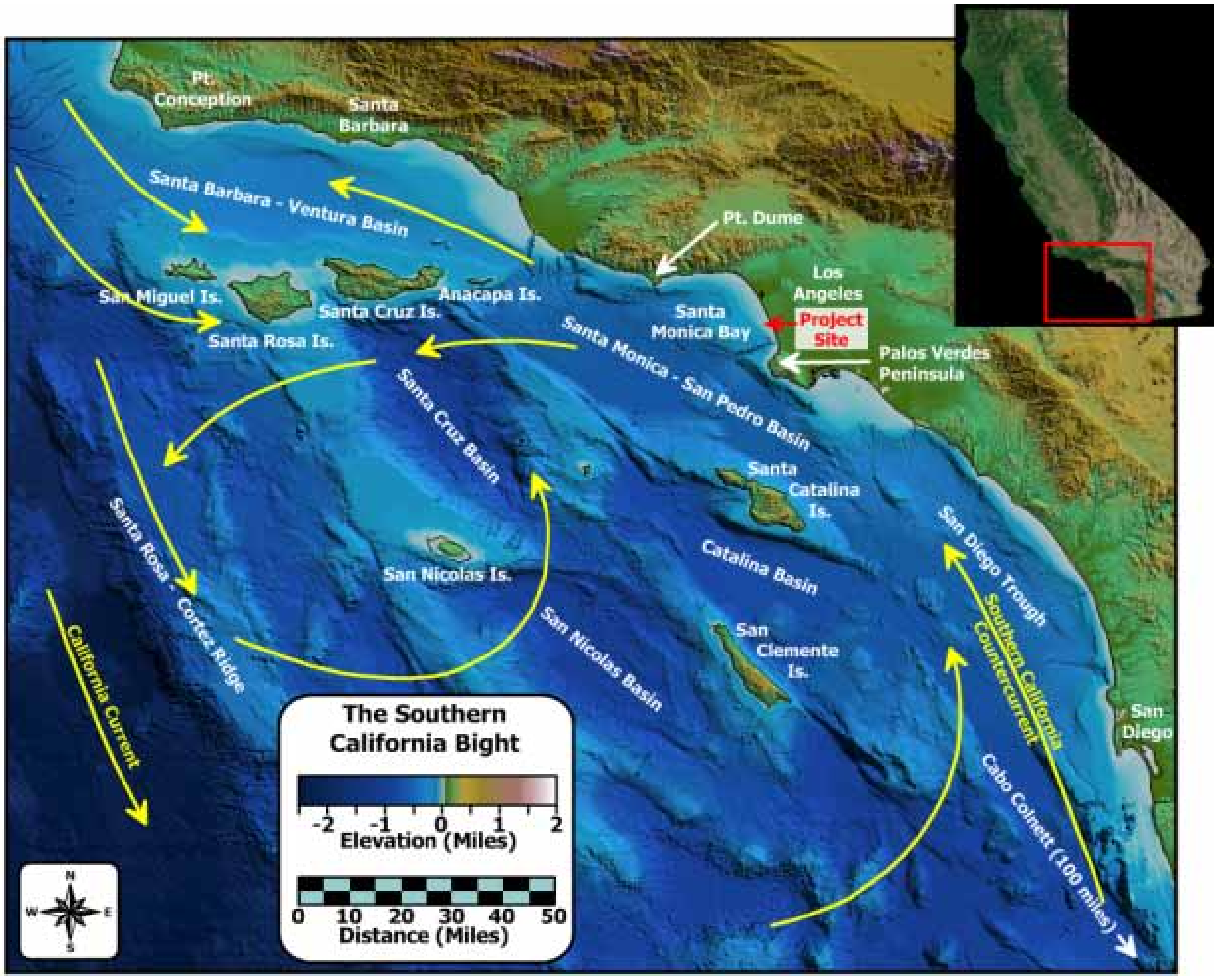
Rainstorm events are largely restricted to the winter season when extratropical disturbances approach California from the west or northwest. Santa Monica Bay experiences from 10 to 30 of these north Pacific weather systems per year. On average, 92 percent of the seasonal precipitation falls between November 1 and April 30. As described in the subsequent sections on seawater properties and pollutants, freshwater plumes that form within Santa Monica Bay from stormwater runoff through Ballona Creek have a profound impact on the Bay's sediment and water quality.

Oceanic Flow

The large-scale oceanic flow field within the SCB is dominated by the California Current System, including the southward-flowing California Current and the northward-flowing Southern California Countercurrent (Hickey 1979, 1992, 1998). The California Current is the dominant oceanic current along the Pacific coast of the United States. The diffuse southward-flowing current represents the eastern limb of the clockwise-rotating gyre that covers much of the North Pacific Basin. Subarctic water, before turning south to form the California Current, is carried along at high latitudes, where it is exposed to precipitation, atmospheric cooling, and nutrient regeneration. As a result, waters of the California Current are characterized by a seasonably stable low salinity, low temperatures, and high nutrient concentrations. Waters within the California Current undergo less seasonal variation than surface waters at similar latitudes along the eastern seaboard.

The California Current transports cool subarctic water southward along the California coast past Point Conception, where it separates from the coast and continues southward beyond the offshore reaches of the SCB (see Figure 4.2-7). Within the southern SCB, portions of the California Current turn inward toward the coast, where they combine with the northward-flowing Southern California Countercurrent, and form a large, counterclockwise-rotating eddy. In contrast to the seawater properties of the California Current, the Southern California Countercurrent brings warmer, saltier, subtropical water northward along the coast.

Figure 4.2-7
Schematic of Surface Circulation within the SCB

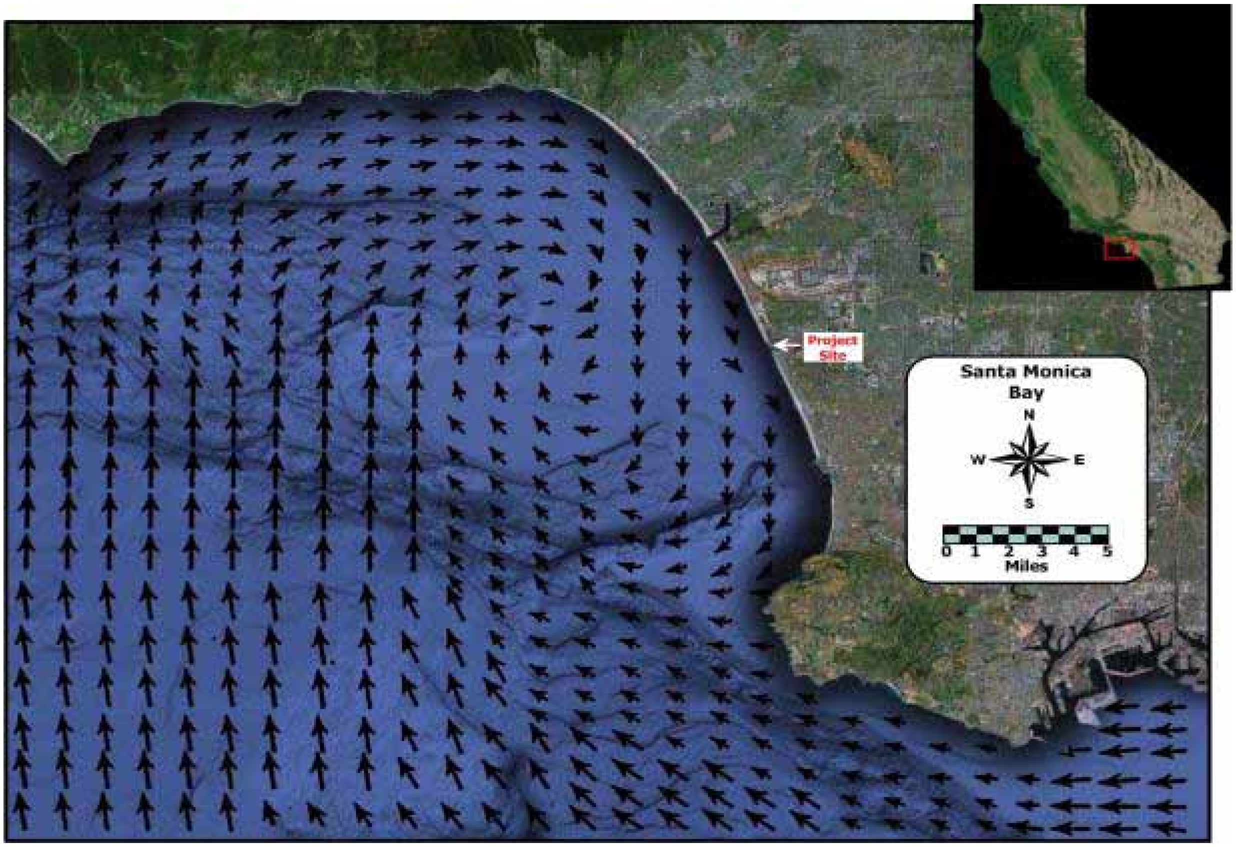


Source: Hickey 1972

This northward-flowing coastal current traverses the mouth of Santa Monica Bay, and occasionally forms a diffuse clockwise-rotating eddy within the Bay (see Figure 4.2-8). However, at any given time, low-frequency[1] currents within Santa Monica Bay are complex and variable. Flow complexity near the Project site is a product of competing processes, including local wind patterns, local and remote oceanic pressure gradients, tides, internal waves, and littoral currents driven by surface gravity waves impinging on the shoreline at oblique angles.

[1] Low-frequency currents fluctuate at periods longer than a day and, therefore, exclude most of the tide- and wave-induced flow.

Figure 4.2-8
Surface Current Vectors within Santa Monica Bay



Source: CSLC 1995

To some degree, seasonal surface-circulation patterns within the SCB and Santa Monica Bay respond to large-scale changes in coastal surface winds (Di Lorenzo 2003). Normally, the Southern California Countercurrent is driven by an alongshore oceanic pressure gradient that forces coastal waters to move in a northwestward direction that is opposite of the prevailing winds that blow from the northwest. As a result, variation in the speed of the Countercurrent is somewhat dependent on the strength of the opposing winds, and the current is strongest when the opposing northwesterly winds relax, which usually occurs between December and February.

However, Hickey et al. found that the majority of the flow variability within Santa Monica Bay is actually driven by the fluctuations in the large-scale along-shore oceanic pressure gradient, which results from forces generated well outside the Bight, rather than by local wind stress over the bay (2003). As a result, currents can flow in a uniform direction throughout the Bay or, at any given time, they can flow in a clockwise or counterclockwise gyre within the Bay. The mean circulation pattern within the Bay during spring and summer can even form a double gyre, with southeastward nearshore flow along the coastline in the lower half of the Bay and northwestward coastal flow in the northern reaches. These various mean flow patterns tend to persist for 10 or more days with typical flow speeds of 0.3 to 0.5 mph (15 to 21 centimeters per second [cm/s]).

Although currents within the Bay generally follow isobaths, the deeply excised Redondo Canyon exerts little topographic influence on the surface flow. However, deep counterclockwise flow within the canyon tends to track the canyon walls. Otherwise, strong pulses of predominantly cross-shelf flow are rarely observed in low-frequency current records, especially near the seabed, where speeds are generally less than 0.1 mph (6 cm/s) (Noble and Xu 2003).

While the strength and duration of these low-frequency flows are capable of transporting suspended particulates and associated contaminants along the shoreline and out of the Bay, two- to four-hour-long pulses of sheared cross-shore flow are primarily responsible for transporting fine sediment and associated contaminants off, rather than along, the shelf. Because of their vertical shear, these pulses transport suspended material near the surface shoreward, in a direction opposite of the deep flow.

The abrupt onset of these sheared current pulses every 12 or 24 hours, depending the diurnal strength of the falling spring tide, indicates that they are internal bores generated over the shelf break by tidal forces. The tidal bores propagate across the shelf and dissipate much of their energy by the time they reach a water depth of 115 feet (35 m). However, farther offshore, seabed flow routinely reaches one mph (40 cm/s), a speed capable of not only resuspending fine-grained material but also medium to coarse sands. Winnowing fine sands and muds from the outer shelf has exposed gravel, cobble, and shell fragments on Short Bank and other deeper portions of the Bay.

Upwelling, wherein nearshore surface waters are replaced by deep cool, nutrient-rich seawater, also affects circulation within the Bay. Upwelling events begin to occur between March and June, when a rapid transition to strong northwesterly wind transports surface water near the coast offshore and down-coast. The nutrients brought to the surface during upwelling drive primary production (phytoplanktonic bloom) that is the hallmark of the productive fishery along the southern California coast.

For most of the year, however, strong currents flow mainly toward the northwest over the narrow Palos Verdes shelf, where they transport resuspended material and the associated contaminants into Santa Monica Bay.

Tides

While surface gravity waves dominate dispersive processes within the littoral zone,[2] tidal currents control dilution and dispersion throughout the offshore domain, particularly where the Terminal berths and Federal anchorages are located. Local tidal-current velocities are a function of sea level fluctuations caused by the tides. Sea level variation at the Marine Terminal is largely driven by diurnal and semidiurnal harmonic modes that usually produce two high tides and two low tides each day. The amplitude of the semidiurnal tide, with a period of 12.4 hours, predominates, causing a difference in height between successive high and low waters depending on lunar declination. Based on two decades of local sea-level measurements, average daily high-water levels at the Marine Terminal are three feet (1 m), while average daily lows are –2.3 feet (–0.7 m) (Jenkins and Wasyl 2005). A maximum range of approximately nine feet (2.7 m) is possible during spring tidal periods.

The resulting tidal currents at the Terminal flow parallel to the shoreline in a northwestward direction on flood tide and southeastward on an ebb tide. Tidal current speeds diminish with increasing proximity to the shoreline due to friction within this shallow coastal boundary layer. In addition, during tidal reversals, the inshore flow lags behind the offshore flow reversal. The maximum current speeds near the Marine Terminal berths typically range from 0.9 to 1.6 mph (40 to 70 cm/s) with average daily maximum flows of one mph (45 cm/s). Along this section of coastline, tidal currents are ebb-dominated such that over one tidal day (24.8 hours), net transport is downcoast toward the southeast.

Waves

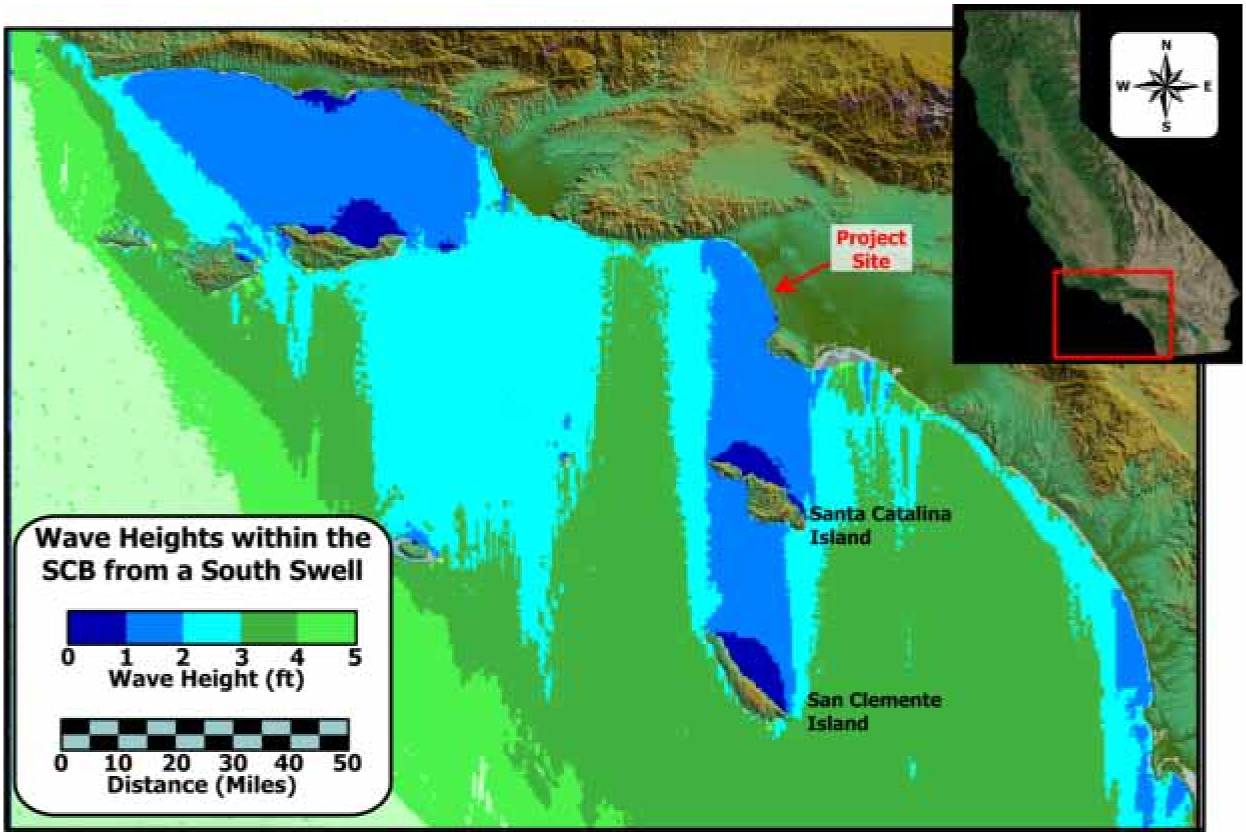
In the very nearshore region of the Marine Terminal, where boundary-layer friction has diminished tidally influenced flow, waves become the principle driving mechanism for flow and dispersion. This wave-dominated region consists primarily of the surfzone, but it also extends seaward into the wave-shoaling zone a few surf-zone widths beyond the point of wave breaking. Waves that approach the shoreline at an oblique angle generate along-shore currents within the Santa Monica Bay littoral cell, which extends 49 miles (78.9 km) from Point Dume to Palos Verdes Point. Wave-induced currents flow along the shoreline in the direction of wave-energy flux and increase in speed with increasing wave height and obliquity. On average, flow is downcoast within this and other littoral cells within the SCB.

[2] The littoral zone is the very nearshore area, which extends from the head of the beach seaward to the limit of wave-shoaling where wave-induced sediment movement can occur.

The surface wave climate within the Santa Monica Bay is a mixture of remotely generated ocean swell and seas produced by local winds. The restricted fetches within Santa Monica Bay and the SCB allow only limited development of locally driven wind waves with correspondingly small amplitudes, short periods, and short wavelengths. In addition, because diurnal land-sea breezes are the most persistent form of winds near the coast, the duration of wind forcing is normally less than 10 hours. It is only when gusty Santa Ana winds prevail, or gale-force winds accompany the passage of winter storms that significant wind waves form. As such, local wind-waves are usually less than 6 feet (1.8 m) in height, with wave periods of less than 10 seconds throughout much of the year. In contrast, remotely generated swells usually dominate the wave field within the SCB.

Two meteorological sources generate significant swell energy offshore California: winter storms that impinge on the California coastline from the northwest and storm swells generated from the south during summer months. However, much of Santa Monica Bay is comparatively sheltered from swells, due to its unique position within the SCB. For example, Palos Verdes Point and San Clemente and Santa Catalina Islands protect the Marine Terminal from southerly swells arriving from angles less than approximately 205 degrees (°) (see Figure 4.2-9).

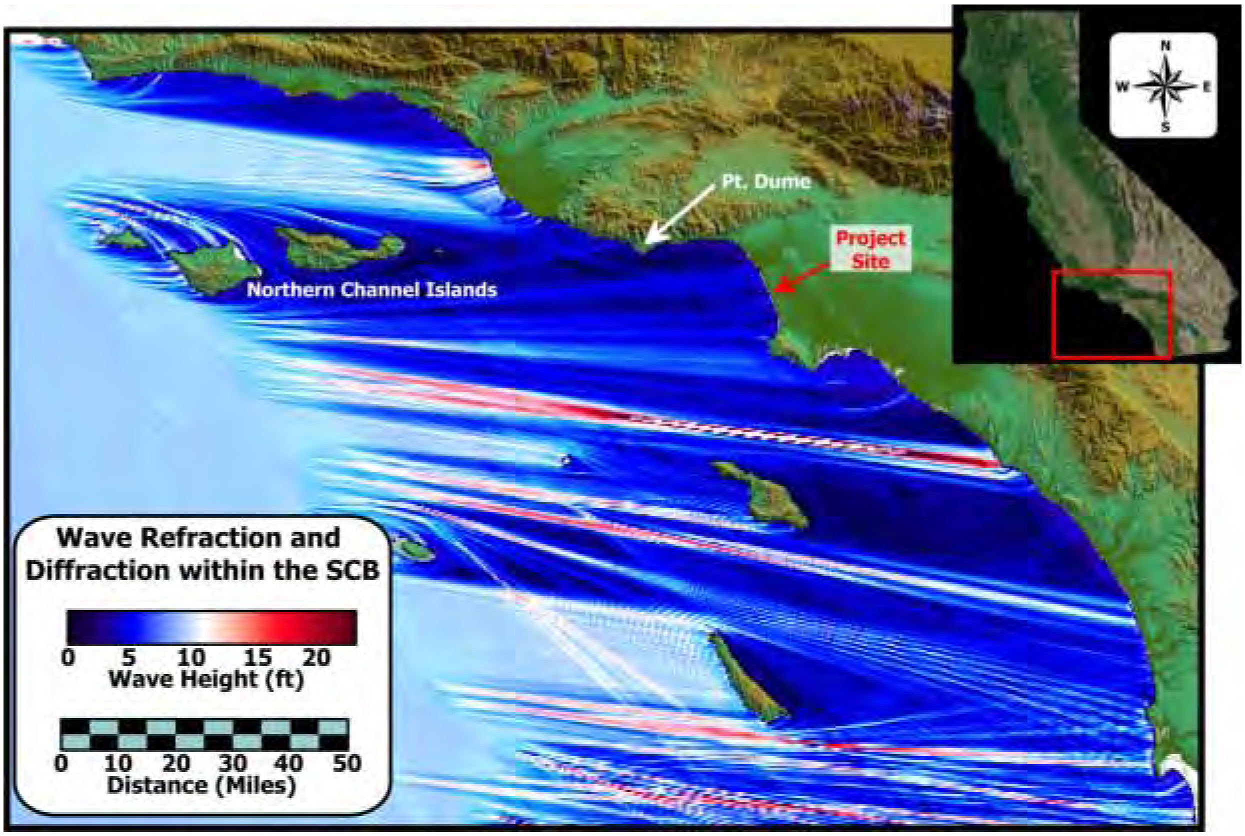
Figure 4.2-9
Deepwater Wave-Height Estimates from a Southerly Swell Event



Note: Swell impinging on the SCB from 180° generated by a tropical depression off the coast of Mexico on September 4, 2008.
Source: Scripps Institution of Oceanography 2009

Similarly, the orientation of the SCB coast and the presence of Point Dume and the northern Channel Islands shelter the Terminal site from most of the effects of swells generated by major winter Pacific Storms that arrive along the coast from the northwest (see Figure 4.2-10). During the event shown in Figure 4.2-10, deep-water swell heights within Santa Monica Bay (shown in dark blue) were only one-third of those offshore of coastal areas where bathymetry had sharply focused wave energy (shown in red) and generated wave heights far exceeding those of the waves that originally impinged on the SCB (shown in light blue). Figure 4.2-10 also demonstrates that the sheltering, diffractive, and refractive effects of the coastline, islands, and nearshore bathymetry interact in complex ways to determine the wave field at any given time.

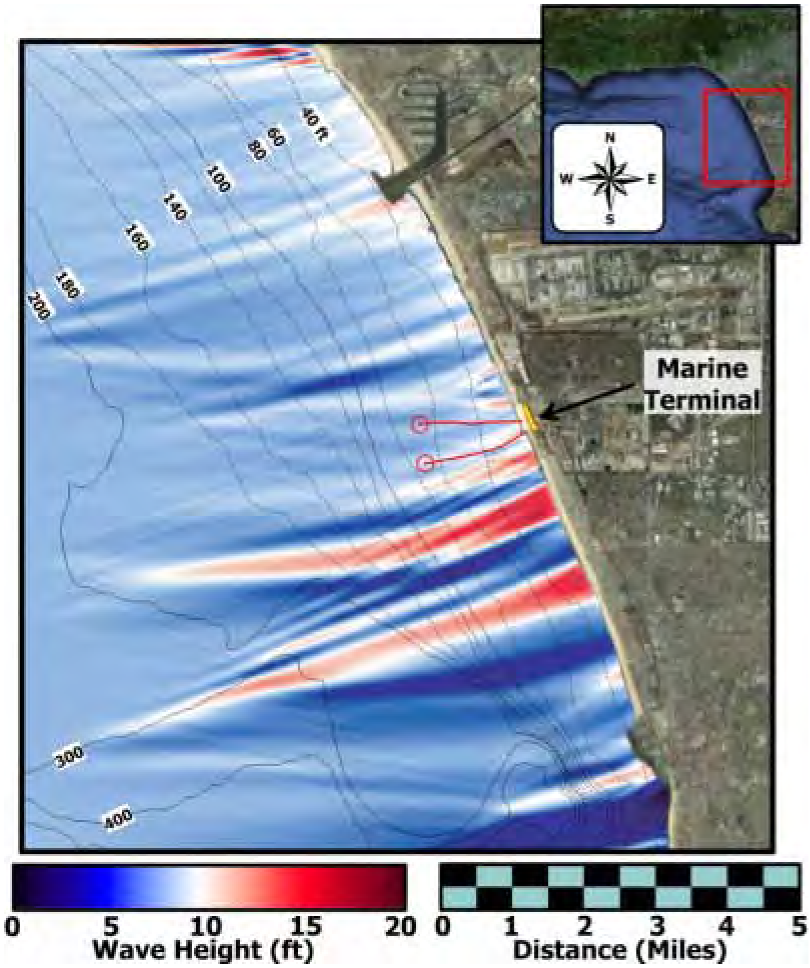
Figure 4.2-10
Complex Wave Field Within the SCB Generated by a Major Winter Storm During an El Niño Event



Note: Swell generated by the El Niño storm on January 13, 1993, with 9.8-foot (3-m), 15-second waves approaching the SCB from 285°.
Source: Jenkins and Wasyl 2005

The interactions that steer and focus deep-water swell are exceptionally sensitive to the direction of the arriving swell. Swells arriving from slightly different directions could result in significantly enhanced wave heights entering Santa Monica Bay. More importantly, nearshore bathymetry can locally amplify swell height as the waves shoal upon approaching the Bay's coastline. This is particularly true of the coastline along southern Santa Monica Bay because of two major bathymetric features: Short Bank and Redondo Canyon. Even though the Bay appears to be in the wave shadow of the northern Channel Islands in Figure 4.2-10, high-resolution analysis of the same swell event near the Marine Terminal reveals highly localized regions of significantly increased wave height (see Figure 4.2-11). Although the deep-water swell height from this storm was 7.4 feet (2.3 m), refraction over local bathymetry created 13-foot (4-m) wave heights immediately south of the Marine Terminal where the shelf narrows near the Redondo Submarine Canyon.

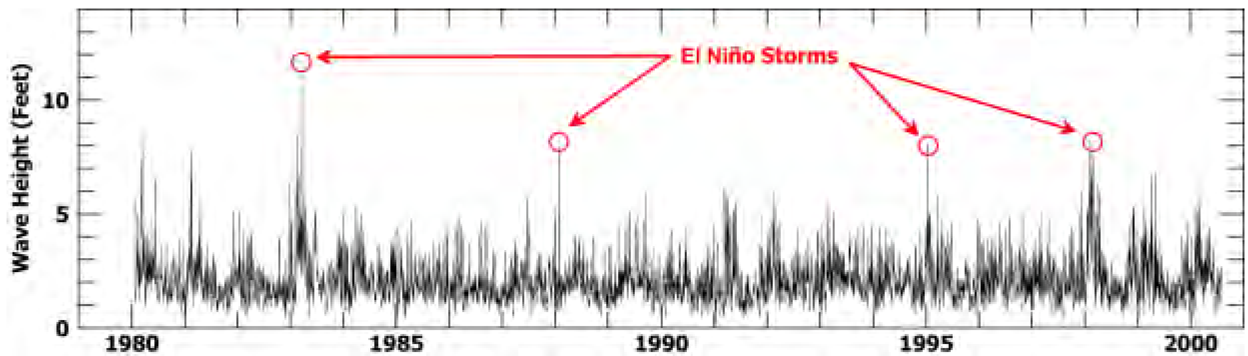
Figure 4.2-11
Swell-Height Patterns Near the Marine Terminal During a Major Winter Storm



Note: Swell generated by the El Niño storm on January 13, 1993, with 7.4-foot (2.3-m), 15-second waves entering Santa Monica Bay from 265°.
Source: Jenkins and Wasyl 2005

Jenkins and Wasyl modeled 21 years of historical refraction patterns like the type shown in Figure 4.2-11, encompassing 7,523 wave events between 1980 and the end of 2000 (2005) (see Figure 4.2-12). Although average deepwater wave heights offshore of the Marine Terminal for this period were 2.5 feet (0.76 m), the time series depicts a number of singularly large swell events that propagated through the wave window open to the Terminal during five El Niño periods from 1982 to 1983, 1987 to 1988, 1994 to 1995, and 1997 to 1998. The largest of these swell events was the March 1, 1983, storm, which produced an 11.5-foot (3.5-m) deepwater swell at the Terminal.

Figure 4.2-12
History of Deepwater Swell Height at the Marine Terminal

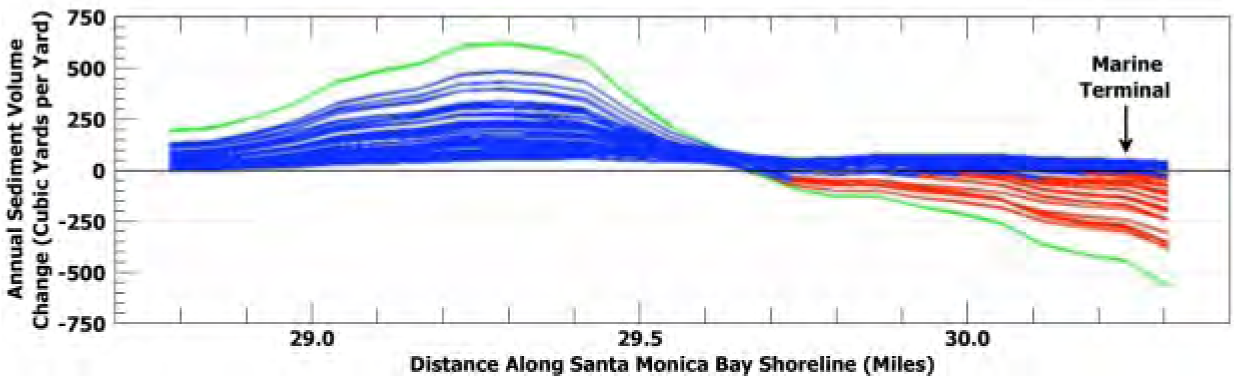


Source: Jenkins and Wasyl 2005

Waves from the March 1983 storm and subsequent El Niño storms severely eroded the beach and seafloor adjacent to the Marine Terminal. In response to severe erosion from the 1983 storms, Chevron constructed a protective peninsula of rocks, called a groin, near the southern boundary of the Marine Terminal. Originally, the groin was 900 feet long (274.3 m) with an elevation 12 feet (3.7 m) above mean lower low water (MLLW). The first 450 feet (137.2 m) of the groin were constructed out of concrete and the remainder with rock. The submerged rock portion of the groin was designed to be semipermeable to sand and allow some alongshore sediment transport. Winter storms in 1985 and 1986 destroyed approximately 160 feet (48.8 m) of the seaward extent of the groin. Repairs to the groin in 1987 added approximately 60 feet (18.3 m) to the groin, which now extends 800 feet (244.8 m) offshore.

During most years, the beach in front of the Marine Terminal has a net erosional potential (see Figure 4.2-13). Erosion potential was most pronounced during the severe El Niño winter of 1982 to 1983, with net losses of 400 cubic yards for each yard (335 cubic meters [m^3] for each m) along the beach, as shown by the green line in Figure 4.2-13. The erosion potential of this section of beach arises because coastal bathymetry tends to focus shoaling-wave energy, shown by red and white areas in Figure 4.2-11. During major wave events, alongshore littoral transport tends to move sand away from these bright spots and toward shadow areas, where net sediment accretion occurs and cross-shore rip currents form.

Figure 4.2-13
50-Year Hindcast of Erosion Potential along El Segundo Beach



Note: Annual potential beach-volume change was computed from the divergence in alongshore littoral drift based on wave refraction-diffraction analyses similar to that shown in Figure 4.2-11. It does not account for limitations in sediment supply. Blue lines indicate years of net accretion, red lines show net erosion, and the green line reflects the severe El Niño winter of 1982 to 1983.
Source: Adams and Inman 2009

Apart from these infrequent extreme wave events, which are principally responsible for major changes in coastal geomorphology, alongshore sediment transport within the Santa Monica Bay littoral cell is downcoast, toward Redondo Submarine Canyon. Upcoast sediment sources within the littoral cell include artificial beach-nourishment projects and the small streams in the Malibu, Topanga, and Ballona watersheds. Historically, Redondo Canyon acted as a sink for sediments but coastal structures along the Bay have stabilized the beaches and reduced losses to the Canyon. The King Harbor Breakwater, in particular, impounds large volumes of sediment that would have normally flowed down the canyon (Leidersdor et al. 1993). Although there are no quantitative data on the present sand permeability of the seaward-most section of the El Segundo Groin, judging from the extent of supratidal sand buildup behind the groin, which does not extend much past the shoreward portion of the rock section (see Figure 4.2-14), its permeability appears to be intact and it is not excessively restricting downcoast transport of littoral sediments.

Figure 4.2-14
Present Configuration of the El Segundo Rock Groin

Climate Change

Long-term fluctuations and trends in the climate of the Pacific Ocean Basin also affect local oceanographic conditions within Santa Monica Bay. The Pacific Decadal Oscillation is a long-lived El Niño-like pattern of Pacific climate variability. These interdecadal events last for 20 to 30 years and the most recent warm regime has been correlated with changes in marine ecosystems in the eastern Pacific Ocean (Francis and Hare 1994). In addition, there is a growing scientific consensus that the warming trend in recent decades has been exacerbated by human activities that have increased the amount of greenhouse gases in the atmosphere (National Academy of Sciences 2008).

Of particular concern are potential impacts to coastal communities, infrastructure, and ecosystems from the associated global rise in sea level. Lands under the jurisdiction of the CSLC are particularly vulnerable to increased storm intensity and sea level rise associated with climate change, and the CSLC has initiated studies to assess the effects of sea level rise on existing coastal facilities (CSLC 2009). Recommendations include a provision in leases requiring lessees to comply with future standards that may be adopted by regulatory agencies that address sea level rise, and a requirement to evaluate the structural integrity of coastal facilities that may be impacted as sea levels rise. Based on various scenarios of climatological response to increased greenhouse gas emissions, sea level along the California coast could rise 16 inches (41 cm) by 2050 and 55 inches (140 cm) by 2100 (Cayan et al. 1999). Such a rise would significantly increase the number of coastal residents and structures that are at risk from coastal inundation during the 100-year flood event and would accelerate coastal erosion (Heberger et al. 2009).

Seawater Physicochemistry

The physical and chemical properties of seawater are regularly used to evaluate marine water quality. Throughout the SCB, the Southern California Coastal Water Research Project, the Surface Water Ambient Monitoring Program, and the California Cooperative Oceanic Fisheries Investigations conduct regional assessment programs. Within Santa Monica Bay, numerous NPDES permits require individual point-source dischargers to regularly monitor receiving water properties. Near the Marine Terminal, the NPDES discharge permit issued to the Refinery requires regular measurements of temperature, salinity, turbidity, hydrogen-ion concentration (pH), dissolved oxygen, trace-metal concentration, and bacterial densities (LARWQCB 2006). This subsection examines the spatiotemporal variability of these properties within Santa Monica Bay and establishes their baseline levels near the Terminal.

Physicochemical properties within Santa Monica Bay exhibit distinct seasonal variations and spatial distributions that arise from the interaction among bottom topography, vertical mixing, horizontal advection, freshwater discharge, and biological processes (Nezlin et al. 2004). The seasonal cycles exhibit three basic patterns: (1) a cross-shore gradient; (2) a balance between water masses transported by the California Current from the northwest and the Southern California Countercurrent from the south; and (3) freshwater discharge from Ballona Creek, whose mouth is located near Marina del Rey.

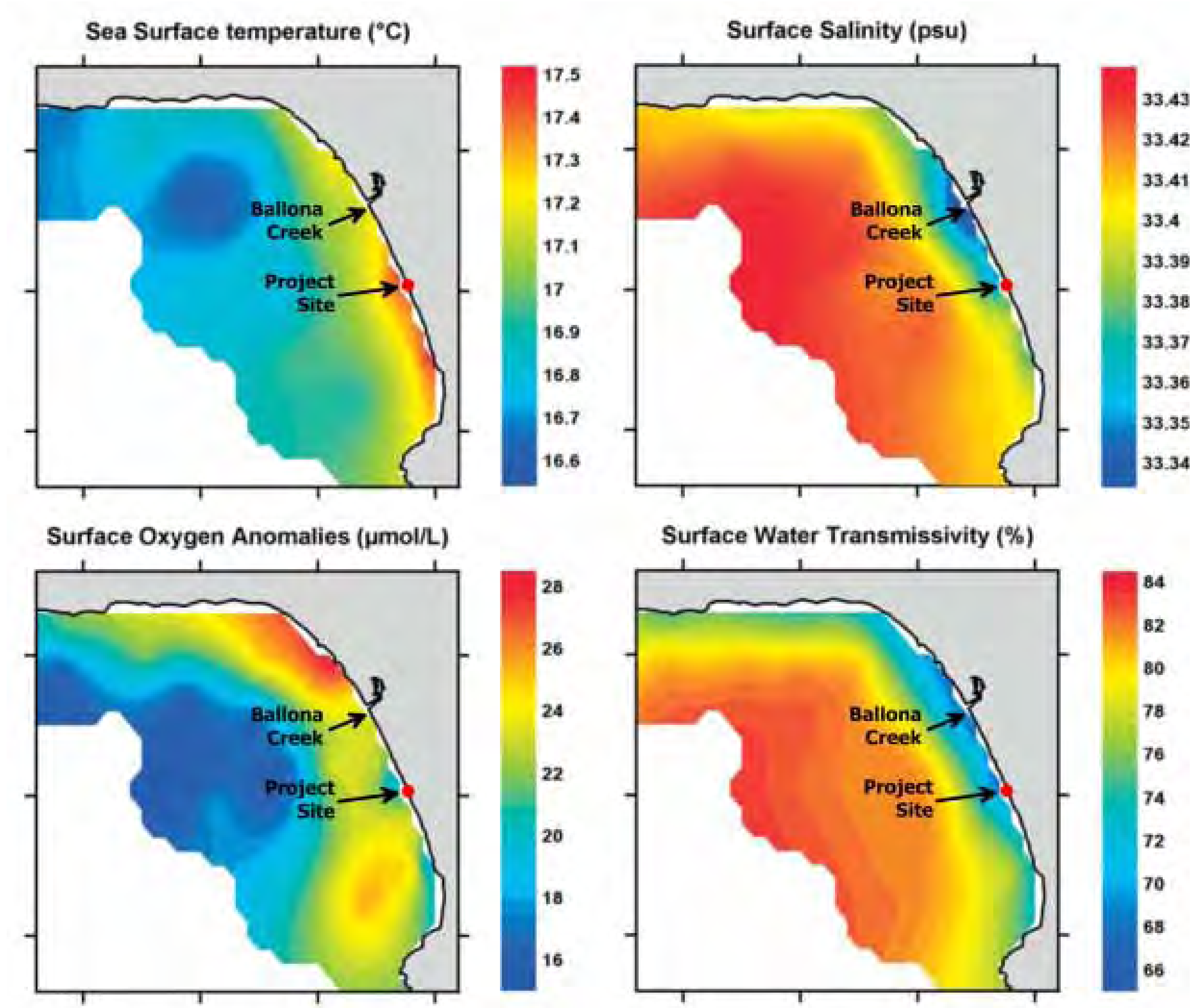
The annual average spatial distribution of the primary seawater properties shows that surface salinity and water clarity (percent transmissivity) tend to be lower near the Marine Terminal and along the coastline extending to the north past Ballona Creek, than in most other areas of the Bay (see Figure 4.2-15). In contrast, sea-surface temperatures and dissolved-oxygen concentrations tend to be higher at the Terminal than in central Santa Monica Bay.

Salinity

Annual mean salinity is relatively uniform across the entire Bay, with values close to 33.40, except for a zone of low salinity along the coast with the lowest values found near the mouth of Ballona Creek (upper-right frame of Figure 4.2-15). Freshwater discharge centered at Ballona Creek is responsible for the reduced average salinity observed at the Terminal. However, its influence is intermittent and relegated to isolated winter rainstorm events, which also transport pollutants from the land into the coastal seas (Dwight et al. 2002, Ackerman and Weisberg 2003).

Figure 4.2-15

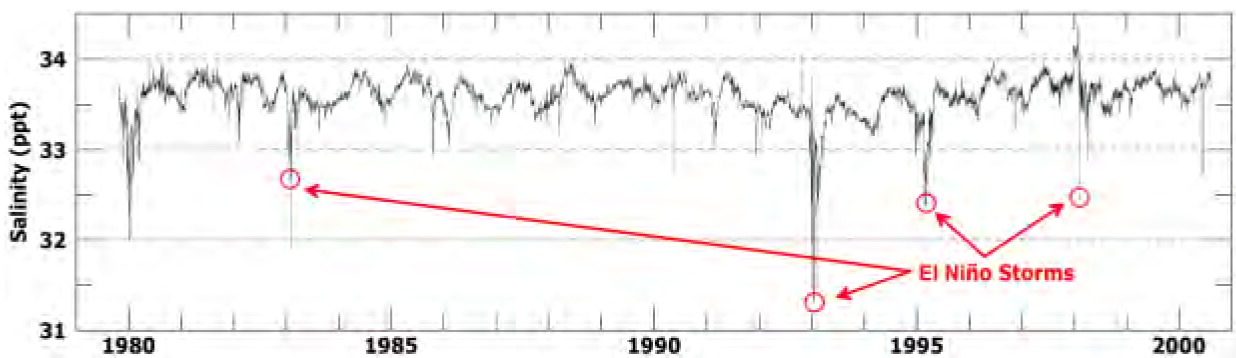
Annual Average Distribution of Seawater Properties within Santa Monica Bay



Source: SCCWRP 2004

Because of the cumulative influence of winter-storm runoff into the sheltered Santa Monica Bay, seasonal average salinity at the Marine Terminal typically decreases by ten percent in winter from the summer maximum (see Figure 4.2-16). However, much larger fluctuations are evident on shorter time scales. Maximum salinity was 34.34 parts per thousand (ppt) during the summer of 1998 when southerly El Niño winds enhanced the northward transport of high salinity water from southern Baja into the SCB. Minimum salinity was 31.02 ppt during winter floods of 1993. Except during these kinds of isolated events, vertical salinity gradients tend to be negligible compared to thermal stratification near the Marine Terminal, although surface salinities tend to be slightly higher when the water column is stratified (Chevron 2006, 2007abcd, 2008c).

Figure 4.2-16
Daily Mean Seawater Salinity near the Marine Terminal

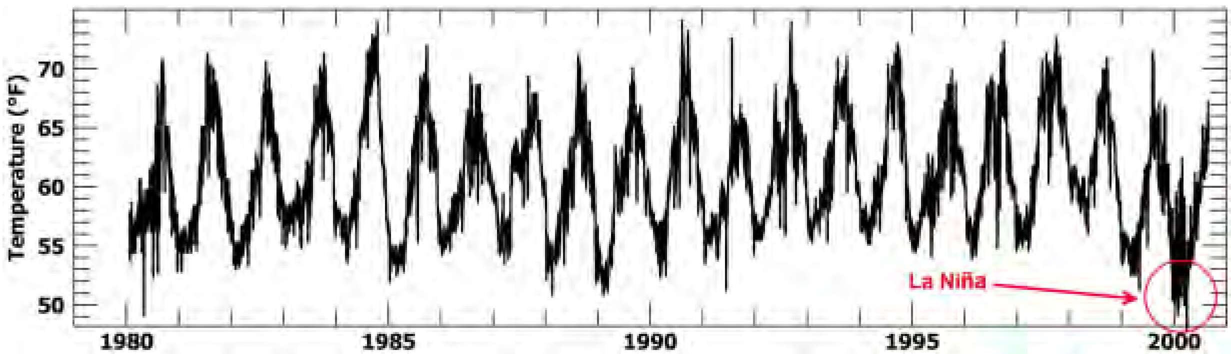


Source: Jenkins and Wasyl 2005

Temperature

Surface water temperatures in the SCB typically range from 52 to 73 degrees Fahrenheit (ºF) (11 to 23 degrees Celsius [ºC]), with winter and spring temperatures lower than summer and fall temperatures (see Figure 4.2-17). Compared to the salinity record at the Marine Terminal, sea-surface temperature exhibits a more pronounced seasonal variation over the twenty-year record. As a result, interannual variability is less apparent, although depressed temperatures associated with the 1999 to 2000 La Niña event can be discerned. La Niña events are the opposite of El Niño events. La Niña events are characterized by a strengthening of the California Current relative to the Southern California Countercurrent, resulting in tangibly lower fall and winter seawater temperatures. During the 1999 to 2000 La Niña event, sea surface temperatures near the Marine Terminal dropped to 49°F (9.4°C), the lowest temperature recorded over the twenty-year record.

Figure 4.2-17
Daily Mean Sea-Surface Temperature near the Marine Terminal



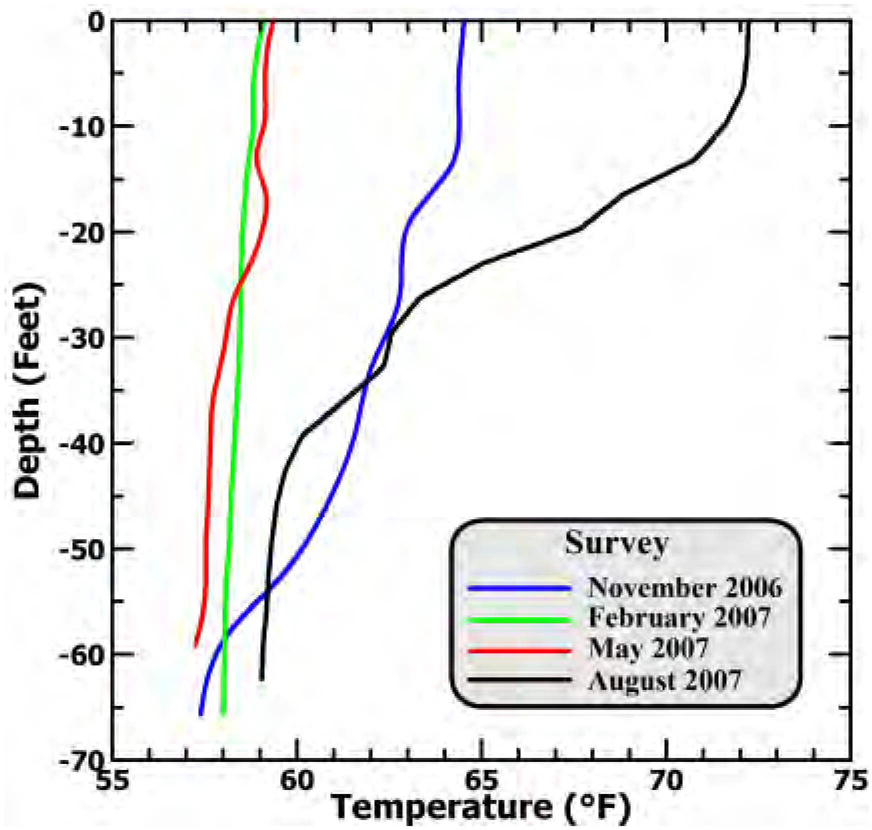
Source: Jenkins and Wasyl 2005

A strongly stratified water column restricts the vertical exchange of water parcels and limits initial dilution of contaminants released near the seafloor, such as those discharged from wastewater outfalls. Similarly, stratification reduces the tendency for surface contamination, such as an oil spill, to mix downward into the water column. Stratification of the water column is largely dictated by vertical temperature gradients, except when freshwater plumes from stormwater runoff are present. Near the Marine Terminal berths, vertical stratification varies seasonally and is largely dependent on the strength of local upwelling and the amount of insolation (see Figure 4.2-18).

The February profile (shown in green in Figure 4.2-18) exemplifies unstratified conditions typical of winter, when passing storms mix the water column and produce nearly uniform conditions. In May (shown by the red profile), a thermocline begins to form as upwelling starts to transport slightly cooler water shoreward at depth to replace surface waters transported offshore by prevailing winds. As the frequency and intensity of upwelling events build during the summer, and increased insolation heats surface waters, large differences between surface and bottom temperatures become apparent. The August profile (shown in black) captured a 13°F (7.2°C) difference across a 30-foot (9.1-m) thick thermocline. As upwelling and insolation wane during fall months, mixing processes erode the sharp thermocline, and thermal stratification tends to extend throughout the water column (as shown by the blue profile).

Figure 4.2-18

Vertical Profiles of Seawater Temperature Near the Marine Terminal Berths



Note: Measurements were collected at Station RW16, immediately shoreward of the Marine Terminal Berths (see Figure 4.2-6).
Source: Chevron 2006, 2007abd

Dissolved Oxygen

In combination with nutrients, dissolved oxygen is necessary for a healthy marine ecosystem. Pollutants high in organic constituents can locally deplete oxygen levels and deleteriously affect marine organisms. Oxygen depletion arises from the bacterial degradation of oxidizable components in organic wastes. In extreme cases, this additional oxygen demand can reduce dissolved oxygen levels to below those necessary to support biological processes. Because of this, the California Ocean Plan limits the discharge of oxygen-demanding constituents within wastewater so that the resulting depression in dissolved-oxygen concentrations does not exceed 10 percent from natural conditions (SWRCB 2005a). Anoxic conditions can occur in the water column as well as in seafloor sediments, although their occurrence in the well-flushed open ocean is rare. Nevertheless, anoxic conditions occur naturally at the water-sediment interface in many of the deep basins within the SCB (Dailey et al. 1993).

Surface waters at the Marine Terminal are usually supersaturated with oxygen because of photosynthetic activity and bubble entrainment by surface gravity waves. Saturation levels, which range from 6 to 11 percent, are largely determined by sea-surface temperature because it is the primary factor determining gaseous solubility at the air-sea interface. Below this surface maximum, dissolved-oxygen levels steadily decrease with depth due to natural losses from biotic respiration and decomposition, and from the lack of exchange with the atmosphere. Under stratified conditions during upwelling, dissolved-oxygen levels decrease rapidly with depth. The low oxygen concentrations at depth are a consequence of the shoreward movement of deep, oxygen-poor waters that have not been in recent contact with the atmosphere, and where ongoing respiration and decomposition have extracted much of the available dissolved oxygen.

Hydrogen-Ion Concentration

The pH of marine waters in the study region is similar to that of seawater in most other oceans of the world. It is slightly alkaline, with a pH ranging between 7.5 and 8.5. The lack of strong geographic variation in pH is a consequence of the well -buffered nature of the ocean's carbonate system. The highest pH levels occur at the Marine Terminal during spring upwelling, when increased photosynthesis consumes carbon dioxide (CO_2) and produces oxygen near the sea surface. As the ratio of respiration to photosynthesis increases with depth, there is an increase in dissolved CO_2 (carbonic acid) and a corresponding decline in pH as the waters become more acidic.

The pH of ambient seawater can also be impacted by the discharge of certain types of pollutants, particularly if the substances are caustic (pH>12), like Portland or hydraulic cement used in marine construction, or strongly acidic (pH<3). Even then, however, the well-buffered open ocean quickly moderates pH excursions, so the effects tend to be temporary and localized. Nevertheless, the California Ocean Plan restricts the discharge of pH-altering substances so they do not change the receiving seawater pH by more than 0.2 units from natural conditions.

Seawater Clarity

Water clarity, transparency, transmissivity, ambient light penetration, turbidity, and suspended-solid concentrations all reflect how well water transmits light. Turbidity decreases the clarity of seawater and can limit the penetration of ambient light in the upper reaches of the water column. It is largely determined by the concentration of suspended particulate matter and, within the upper water column, turbidity dictates the depth of the euphotic zone. The base of the euphotic zone is where ambient light intensity is reduced to roughly one percent of surface illumination, which is the minimum necessary for phytoplankton growth. Turbidity increases in coastal waters as a result of phytoplankton blooms, storm and freshwater runoff, sediment resuspension, and wastewater discharges from seafloor outfalls. Within the SCB, substantial particulate input from creek runoff generally occurs in the form of large isolated pulses rather than a steady discharge of terrigenous material. Rare, intense storm events occasionally punctuate the prevailing semi-arid climate. Such storms generate large amounts of turbid runoff, which results in profound but transient increases in coastal turbidity.

Anthropogenic reductions in the transmission of ambient light in the upper water column are of greatest concern because they limit the depth of the euphotic zone and thus primary production (phytoplanktonic photosynthesis) and macroalgal (kelp) growth. In recognition of this, NPDES permits restrict the volume and concentration of suspended solids contained within point-source discharges, including the Refinery's wastewater discharge. The California Ocean Plan requires that a wastewater discharge not cause a significant reduction in the transmittance of natural light after initial mixing. However, similar controls are difficult to impose on the discharge of suspended solids within stormwater runoff, dredging activities, construction activities, and natural and harmful algal blooms.

Water clarity within Santa Monica Bay, as measured by annual average transmissivity at the sea surface, is relatively high (see the lower-right frame of Figure 4.2-15). This is particularly true in the central Bay, where surface waters are capable of transmitting 85 percent of the ambient light across a 25-cm path. Light transmittance tapers off to 66 percent near the shoreline where the Marine Terminal is located. The reduced nearshore water clarity reflects the influence of wave-induced sediment resuspension and the influence of Ballona Creek runoff. Because these influences vary markedly over time, transmissivity also has its highest variability within this nearshore region (Nezlin et al. 2004). Water clarity is also reduced within the euphotic zone when upwelling-induced primary productivity (phytoplanktonic blooms) increases the presence of biogenic particulates. On average, the lowest water clarity is found at the end of April, when upwelling winds are typically at their maximum. When combined with increased turbidity near the seafloor from wave resuspension, a mid-depth maximum in transmissivity (water clarity) is often observed in the nearshore region. This vertical distribution differs from that of the other seawater properties, which tend to steadily increase or decrease with depth.

Nutrients

In addition to ambient light intensity, phytoplanktonic photosynthesis depends on the availability of inorganic nutrients, particularly phosphates and nitrates. Factors that influence nutrient concentrations include upwelling, biological processes, wastewater disposal, and stormwater runoff. For the most part, concentrations of nitrate, phosphate, and silicate are negligible within the euphotic zone due to rapid uptake by phytoplankton. However, sewage and surface-water runoff can contain high levels of nitrogen and phosphate, and can locally alter nutrient levels within receiving waters.

Excessive nutrient loading can lead to harmful phytoplankton (algal) blooms within surface waters and impact dissolved-oxygen levels. Within the SCB, marine impacts are primarily caused by recurring blooms of *Alexandrium* and *Pseudo-nitzschia* that produce potent neurotoxins (Schnetzer et al. 2007). These neurotoxins accumulate in fish and shellfish that are ingested by mammals, including humans, and cause paralytic and amnesic shellfish poisoning. Bioaccumulation of algal toxins through the food web has been linked to significant wildlife mortality events of fish, birds, and marine mammals, especially protected species like sea lions.

Hydrocarbons

Hydrocarbons enter Santa Monica Bay from a wide variety of sources, including wastewater discharge, atmospheric fallout, naturally occurring seafloor seeps, and oil spills. Some of most toxic forms are the polynuclear aromatic hydrocarbons (PAH). The Hyperion Treatment Plant discharged 23 metric tons (MT) of PAH into the Bay in 2004. Near the Marine Terminal, seawater concentrations of these and other hydrocarbons are consistently below detectable levels (Chevron 2007a, 2007d). However, near the mouth of Ballona Creek sediments have been contaminated with PAH from onshore runoff. In addition, a number of natural seeps introduce hydrocarbons to the Bay along the Palo Verdes Fault, which trends to the northwest from the Palo Verdes Peninsula to the center of the Bay (see Figure 4.2-2). For the most part, however, background hydrocarbon concentrations within Bay waters are negligible compared to those that could accidentally be introduced by a major oil spill.

Seawater Metals, Dissolved Organic Compounds, and Bacteria

In contrast to organic contaminants, most trace metals occur in detectable concentrations within seafloor sediments, and to some degree, in a dissolved form within the water column. Near the Marine Terminal, low but detectable concentrations of dissolved arsenic, copper, lead, mercury, and zinc were found in seawater samples